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MEASURING THE SPECTRUM OF CLOUD DROPLETS

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ABSTRACT

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A brief review is given of the methods used in measuring the spectrum of cloud droplets. Data are presented on the simultaneous measurement of droplet spectra in a stream using devices with different capture coefficients. Experimental results fail to confirm the correctness of the theoretical factors for droplet capture obtained earlier for the instruments.

At the present time about the only method of obtaining data on the /18* distribution spectrum of cloud and fog droplets is the method of inertial precipitation from the stream on a flat plate. Different methods are used for the fixation of droplets which have reached the surface of the plate. The fixation of droplets in oil of required consistency is most frequently used. This method was proposed by N.A. Fuks (ref. 9) and later developed by A.M. Borovikov (ref. 2), V.A. Zaytsev (ref. 3) and S.S. Khmelevstov (ref. 10). The method first proposed by L. Strazneveskiy (ref. 23) is used less frequently. In this method the replicas of droplets are obtained on glass covered with soot. May (ref. 18) and Frith (ref. 15) used magnesium oxide films instead of soot.

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*Numbers given in the margin indicate the pagination in the original foreign text.

There are also methods which use 2-layer films usually consisting of soot covered with a thin protective layer of magnesium oxide (ref. 4).

In recent years many experiments have been carried out utilizing films of pure gelatin for fixating droplets or rather their impressions. May (ref. 19) used pure gelatin, Okita (ref. 21), Liddele and Wootten (ref. 17), and Godard (ref. 16) used gelatin films with dyes, Farlow (ref. 14) used films with a corresponding reagent while Sivadjian (ref. 22) and Ravinskiy (ref. 7) used a more complex method of processing the films. In the May method special illumination is necessary for the detection of droplet impressions while in the other methods the impressions are colored and can be measured using a conventional microscope.

The simplest method is one of capturing droplets by means of an oil film, because the preparation of the glass is not difficult and the droplets have their natural size on the test glass. The only requirement is that the test samples be photographed in as short a period of time as possible because the droplets may evaporate or dissolve in the oil. Also it is possible that part of the droplets will be lost because they are situated at different levels within the oil layer. It is also possible that the spectrum will become distorted because the droplets fuse in the oil. Unfortunately the method of capturing droplets with oil films can be used only aboard airplanes which are not pressurized.

The method of capturing droplets by means of a plate covered with soot requires a more complicated procedure in preparing the glass. Usually the glass must be prepared in advance and measures have to be taken to protect the soot layer from damage during storage. Compared to the oil method this method may appear to be more advantageous since the impressions produced by the /19

droplets lie in one plane. The error produced by the fusion of droplets is practically eliminated because two double impressions of a droplet, as a rule, can be measured independently. This method can also be used in pressurized airplanes equipped with completely automated devices, because the impressions of droplets may be stored for a prolonged period of time without changes.

However, the method has a series of shortcomings. First, the diameter of an impression does not correspond to the true diameter of the droplet, which makes it necessary to use transfer coefficients. In the second place, the variation in the diameter of the impression as a function of soot thickness requires a uniform soot layer which must always have the same thickness. In the third place, the protective layer is frequently so dense that small particles are unable to penetrate it and produce impressions. Finally, as shown by G.D. Salamandra and I.M. Naboko (ref. 8), it is possible to obtain several impressions from the same droplet, due to its multiple rebounds from the base layer.

The methods of capturing water droplets with a gelatin film are proposed primarily as supplementary to the method of capturing with a layer of soot because they make it possible to capture droplets of smaller size. In these methods it is very important to determine the transfer coefficient which makes it possible to establish the true dimensions of the droplets from the measured dimensions. The method of determining this coefficient has not been worked out in a sufficiently rigid manner to date.

The common shortcoming of all of the methods for capturing cloud droplets is that not all the droplets in the volume of air flowing towards the plate reach its surface. The theoretical calculations of A. Kh. Khrgian, and I. P. Mazin (ref. 11) and L. M. Levin (ref. 4) and all other investigators have shown that the capture coefficient (ratio of the quantity of droplets of a given size which

has settled on the plate to the quantity of droplets contained in the volume from which the droplets settled) is a function of the dimensionless parameter $P = \frac{2ur^2}{9\mu A}$ where μ is the flow velocity, r is the radius of the droplets, A is the characteristic dimension of the plate (width), μ is the coefficient of air viscosity.

For some critical value P_{cr}, the capture coefficient E becomes equal to 0. This means that the droplets whose radius is less than some critical value (corresponding to the critical P_{cr}) cannot be captured by the plate, for theoretical reasons. For droplets whose radius is greater than the critical value, it is necessary to introduce corresponding corrections. For droplets which are slightly greater than r_{cr} the magnitude of the correction factor is several units.

The above shortcomings of the capture methods, and the difficulty of automating them and of interpreting the data, have been responsible for an intensive search for new methods of measuring droplet spectrum.

In the recent years optical methods for obtaining the spectrum of droplets have been developed. A.G. Laktionov (ref. 5), V.Ya. Basevich (ref. 1) utilized the variation in the intensity of light scattering by droplets as a function of their size. Eldridge (ref. 13) utilized the effect of infrared absorption by droplets in the 1-14 μ range (the measurement base was 1 meter). K.S. Shifrin (ref. 12) proposed the method of determining the spectrum of droplets from observations of light scattering at small angles. The same method was applied by G.D. Petrov (ref. 6).

These methods have many advantages but require complex technology. /20

Finally Vonnegut and Neubauer (ref. 24) propose a method of measuring the dimensions of droplets from the degree of cooling of a thin wire heated with an

electric current. This method has not been widely used because it is difficult to carry out, its efficiency is low, and measurements at high flow velocities are impossible.

In spite of the development of new methods, at the present time the only practical method of measuring the spectra of droplets from an airplane is the method of inertial capture in its different versions. However, quite frequently when measurements are taken in natural clouds, droplets are captured whose dimensions are less than the critical dimensions. According to the data of May (ref. 19), Farlow (ref. 14), and Godard (ref. 16) the method of inertial precipitation can be used to obtain impressions from droplets whose diameter is a few tenths of a micron. At the same time if we take into account the dimensions of the plates which are used and the velocities of the ceilings we can easily see that such droplets lie beyond the critical region. For this reason the experimental investigation of correction factors computed theoretically is of practical interest.

Experiments were conducted in the cloud chamber of the Vysokogornyy Geophysical Institute at Terskol. The fog in the chamber was produced by steaming, then was evacuated from the chamber through a wind tunnel with a cross-section of 25.25 cm and which contained the test droplet collectors. The difficulty of carrying out the experiment was associated with the high moisture content of the cloud chamber and large number of droplets. During operation of the tunnel the density of the fog decreased nonuniformly from its maximum value to zero during a period of 40-60 seconds. In addition to this, its homogeneity was gradually disrupted along the cross-section of the tunnel. The flow velocity along the cross-section of the tunnel varied insignificantly and was approximately 50 meters/sec.

In order to decrease the distortion of experimental data, the time between the collection of droplets and their photographing was reduced to a minimum and did not exceed five minutes. Five to ten pictures were taken of the different regions of each test sample.

To obtain the best capture and retention of particles, the optimum consistency of the oil was selected. The number and dimensions of the particles were computed in the conventional manner. The microphotographs were projected with fixed magnification on paper graduated in millimeters. To establish the scale a micrometer was photographed in each picture.

Two collectors were used to carry out the experiments. One was a standard TsAO Collector with a diameter of 55mm, while the second was a special unit with a diameter of 5mm and a glass width of 3mm. At first both collectors were used separately; later, in order to synchronize the collection of test samples and to provide for equal exposure the small collector was attached to the large one and the displacement of glass was produced by the mechanism of the large collector.

The results obtained after processing the microphotographs obtained in these experiments are shown in tables 1-4. Table 1 presents data on the spectra of droplets obtained simultaneously in different sections of the wind tunnel. In this case the conventional TsAO collector with three slots having widths of 2 4 and 8 mm contained three glasses simultaneously. Table 2 presents data from a similar experiment where the width of the slots in the collector was equal to 2 mm. Table 3 presents data for the simultaneous measurement of the spectrum by means of a wide and narrow collector with different exposures, while table 4 presents the same data but for uniform exposure. During these measurements the collectors were installed in such a way that the operating slot of the wide collector was situated at the position of its first /28

slot in the preceding experiments, while the slot of the narrow collector was at the position at the third slot in preceding experiments.

As we can see from the data presented in table 1, the spectra obtained by means of one collector simultaneously at different regions of the cross-section are sufficiently close to each other. The best reproducibility for all three spectra was obtained with droplets having a diameter of 7 microns and was equal respectively to 24.5, 28.2 and 27.2. The spectra break off with droplets 16-18 microns in diameter. However in this case there is a clear heterogeneity in the numerical concentration of droplets: for one frame of the first slot (2 mm) there are 242 droplets, for the second (4 mm) there are 438 and for the third (8 mm) there are 332 droplets. When going from the 2 millimeter slot to the 4 millimeter slot the number of droplets increases by a factor of 2. When going from the 4 millimeter to the 8 millimeter slot the number of droplets actually decreases by a small amount.

At first glance we might assume that the decrease in the number of droplets is due to their fusion. This proposition was checked by computing the volumes of all the droplets ($\propto\Sigma Nd^3$) for each frame. They were found to be equal to the following: $1.53\cdot10^{-4}mm^3$ for the first slot, $2.56\cdot10^{-4}mm^3$ for the second and $2.49\cdot10^{-4}mm^3$ for the third, i.e., the volume of droplets at the third slot as well as their number did not increase, but rather decreased. Consequently the decrease in the number of droplets in the third slot by a factor of 2 is not due to their fusion. It is due either to the heterogeneity of droplet concentration along the cross-section of the tunnel or, what is most probable, to the loss of droplets when they are photographed.

The spectra shown in table 2 are also close to each other. The best reproducibility occurs, as in the preceding case, for droplets with a diameter

of 7 microns, and is equal to 28.6, 29.3 and 28.7. The spectra break off at 12-13 μ droplets. Since the width of all the slots in this case is the same we should expect the same number of droplets on all the frames. However, in the case of the first slot there are 336 droplets per frame, in the second there are 140 and in the third there are 153; i.e., the quantity of droplets captured in the first slot is greater by a factor of 2 than that captured in the other slots. The quantity ΣNd^3 is also greater by a factor of 2 in the case for the first slot. It is equal to $1.17 \cdot 10^{-4}$ mm^3 while for the second and third slots it equals respectively $0.64 \cdot 10^{-4}$ and $0.73 \cdot 10^{-4}$ mm^3. This example shows quite well that although there are substantial fluctuations in the numerical concentration of droplets captured by the glass (regardless of whether it is a true reflection of the variation in the concentration or is produced by methodological errors), the relative spectrum of the droplets varies insignificantly, which is not true of the moisture content of the cloud determined from the spectrum and the numerical concentration.

We should note that in the first case approximately 50 percent and in the second case approximately 70 percent of all the droplets captured by the collector had a diameter which was not greater than 7 microns. According to theory, such droplets would not be captured with the given collector at all.

Table 3 shows the data which are very close in time (with deviations not greater than several tenths of a second), but with different exposures for measuring the spectrum with two collectors. In this case the exposure time of the narrow collector was less than that of the wide collector. Distribution spectra obtained by means of various collectors turned out to be close to each other, although one would expect a larger relative number of small droplets for the narrow collector compared with that from the wide collector. The best /29

recurrence in the 3 cases occurs for droplets with a diameter of 7-8 μ and varies within the range of 15-18 percent. The spectra break off with droplet diameters of 14-16 μ. In one case the spectrum breaks off with a droplet diameter of 9-10 μ, the maximum recurrence takes place with a droplet diameter of 4 μ while its value for both collectors in this case is equal to 24.8 percent. More than 50 percent of all the captured particles (84 percent in the last case) have a diameter of less than 7 μ; i.e., based on theoretical considerations they should not be captured at all by the wide collector. The narrow collector captures the small droplets with a diameter less than 7 μ more than the wide collector by 5-8 percent. However this value is substantially less than the theoretical value.

Table 4 presents data obtained by the synchronous measurements of the droplet spectrum with the same exposure time. Apparently because measurements were carried out during the warm part of the year, the fog in the chamber consisted of larger particles. In the course of the entire series of experiments droplets with a diameter less than 4 μ were almost not encountered. As in the preceding measurements, in all cases the maximum on the distribution curves obtained by means of the wide and narrow collectors occured for the same droplet size. However only in one case (the second series of observations made on the 19th of August) were the spectra measured by both collectors close to each other in the entire range of dimensions. In this case the density was 264 droplets per 1 mm^2 for the wide collector and 517 droplets per 1 mm^2 for the narrow collector. In all other cases the results of the experiments were somewhat unexpected. Frequently the relative quantity of small droplets captured with the narrow collector was less than the number of the same droplets captured by the wide collector. On the other hand the relative quantity of large droplets captured by the

narrow collector turned out to be greater than that captured by the wide collector. The spectra obtained by means of the narrow collector always contain a rather long loop of large droplets. Such a loop as a rule is not observed in the spectrum obtained by means of the wide collector.

This anomaly is apparently caused because the exposure time of the narrow collector was too long, which produced the large numeric concentration of droplets on the glass of the narrow collector and the fusion of droplets played a substantial rôle. Apparently fusion first produces a loss in small droplets and a much less noticeable increase in the number of large droplets.

Thus fusion produces a sharp decrease in the concentration of small droplets and an insignificant increase in the concentration of large droplets. The data in table 4 confirmed this conclusion. An exception to this is the case shown in table 5, whose data were obtained by averaging out data on the large number of individual frames. In this case the numeric concentration of droplets in the flow or the exposure of the glass were so great that signs of fusion are clearly seen even in the spectrum obtained with the wide collector. The narrow collector captured so many particles that the distribution curve, due to the fusion of particles, became very flat and the spectrum became continuous up to 75 μ, while in all other experiments the spectra broke off at 30 μ, and droplets with a diameter greater than 14-15 μ were hardly encountered in the chamber. Due to fusion, the number of droplets per frame decreased compared with the spectrum obtained with the wide collector by a factor of two. On the other hand, the moisture content computed from the spectrum was more than 10 times greater than the moisture content obtained by means of the wide collector. The ratio of the moisture content according to the narrow collector to the moisture content according to the wide collector in this series of experiments varies from 2 to 10.

Although there was a fusion of droplets even for the wide collector, /30 in most cases over 50 percent of the droplets in the spectra obtained by means of this collector should not have been captured according to theoretical considerations. For the narrow collector where fusion was more pronounced, the number of droplets whose size was less than the critical size did not exceed 20 percent in a series of cases.

Thus the present series of experiments, due to methodological errors has not made it possible to obtain data on the distribution spectra of droplets with two collectors which could be compared with the different chracteristic dimensions. However, it has shown quite clearly that the total capture coefficient of the narrow collector is apparently greater than that of the wide collector by a factor of more than two.

All the experiments described above were conducted using artificial fog. However, natural clouds are encountered which also consist primarily of small droplets. For example, such clouds were frequently encountered during the expedition flights of TsAO in the fall of 1962. As a rule these were disintegrating clouds. Table 6 shows the data obtained during measurements in an isolated field Sc with a power of approximately 80 meters. As we can see from table 6, the distribution spectrum of droplets captured on the glass of the wide collector started with droplet diameters of 4 μ while maximum occurrence was of drops with a diameter of 6-7 μ. Droplets with a diameter greater than 10 μ were practically absent. In this case, 80 percent of the droplets captured by the collector were below the theoretical capture limit.

Conclusions

1. During the inertial capture of cloud droplets from the flow by means of a collector, a large number of precipitated droplets have a diameter which is less than the critical value.

2. No noticeable difference in the nature of the distribution spectra is observed when droplets are captured simultaneously from the flow by means of collectors whose characteristic dimension has a ratio of 1:11. The agreement between spectra is not improved by using existing capture coefficients. Most probably the reason for this lies in the assumptions which are made in computing the capture coefficients (Laminar Properties, flow characteristics, simplified assumptions concerning the shape of the collector, etc.).

3. The actual existence of the difference in capture coefficent of collectors of different sizes has been confirmed experimentally. The integral capture coefficient for a collector with a diameter of 5 mm exceeds the corresponding coefficient of a collector with a diameter of 55 mm by more than a factor of 2.

4. The existence of a limit for the number of particles on a test glass predicted in reference 11 has been confirmed; when the limiting concentration is exceeded there is a substantial distortion of the spectrum corresponding to small droplets.

5. In order to establish the true capture coefficient of various collectors it is necessary to carry out special experimental investigations. Special attention should be paid to the reproducibility of results. It is desirable to carry out more rigid theoretical calculations.

We should point out that similar work to compare different devices used for measuring droplet spectra has been carried out in France at Puy Øe Dôme (ref. 20). A comparison of various devices operating on different principles has failed to produce agreement between the various droplet spectra. Therefore the basic problem of this work, which was to select a standard reference device, was not solved.

TABLE 1. DISTRIBUTION SPECTRA OF DROPLETS OBTAINED SIMULTANEOUSLY AT DIFFERENT CROSS SECTIONS OF THE WIND TUNNEL ON THE 21st OF AUGUST 1962

d, μ	1st Slot (2 mm)				2nd Slot (2 mm)				3rd Slot (2 mm)			
	N	$N, \%$	$\sum_1^d N, \%$	Nd^3	N	$N, \%$	$\sum_1^d N, \%$	Nd^3	N	$N, \%$	$\sum_1^d N, \%$	Nd^3
1	—	—	—	—	—	—	—	—	1	0,04	0,04	1
2	—	—	—	—	—	—	—	—	2	0,08	0,12	8
3	7	0,31		189	—	—	—	—	—	—	—	—
4	55	2,46	3,17	4160	3	0,31		492	—	—	—	—
5	383	17,12	20,29	45825	123	12,62	12,93	15375	67	8,74		8077
6	591	26,43	46,31	127075	251	25,75	38,68	54216	201	26,21	34,95	43116
7	651	28,63	74,93	220208	286	29,35	68,03	98263	229	29,69	64,64	93021
8	310	14,95	89,91	171090	162	16,67	84,70	82944	159	20,73	85,37	83656
9	143	6,29	96,23	104247	88	9,05	93,75	64152	37	4,83	90,20	26973
10	54	2,37	98,60	54000	25	2,57	96,32	25000	35	4,59	94,79	35000
11	15	0,66	99,26	13915	19	1,95	98,27	23589	12	1,56	96,35	17292
12	13	0,57	99,83	22464	9	0,92	99,19	15552	7	0,91	97,26	13608
13	1	0,04	99,87	2197	4	0,41	99,60	8788	2	0,26	97,52	4394
14	2	0,09	99,96	5488	1	0,10	99,70	2744	2	0,26	97,78	5488
15	1	0,04	100,00	3375	—	—	99,70	—	—	—	97,78	—
16	—	—	—	—	1	0,10	99,80	4096	—	—	97,78	—
17	—	—	—	—	—	—	99,80	—	—	—	97,78	—
18	—	—	—	—	—	—	99,80	—	2	0,26	98,04	11664
19	—	—	—	—	—	—	99,80	—	1	0,13	98,17	6859
20	—	—	—	—	—	—	99,80	—	—	—	98,17	—
21	—	—	—	—	1	0,10	99,90	9261	—	—	98,17	—
22	—	—	—	—	1	0,10	100,00	10648	—	—	98,17	—
23	—	—	—	—	—	—	—	—	1	0,13	98,30	12167
24	—	—	—	—	—	—	—	—	1	0,13	100,00	13824
25	—	—	—	—	—	—	—	—	—	—	—	—
Σ	2272	100,00	—	789739	974	100,00	—	416857	767	100,00	—	367
per 1 mm of glass	978	—	—	340000	466	—	—	185000	445	—	—	1[illegible]

TABLE 2. THE DISTRIBUTION SPECTRA OF DROPLETS OBTAINED SIMULTANEOUSLY IN DIFFERENT SECTIONS OF THE WIND TUNNEL ON THE 17th OF AUGUST 1962

d, μ	1st slot (2 mm)				2nd slot (2 mm)				3rd slot (2 mm)			
	N	$N, \%$	$\sum_1^d N, \%$	Nd^3	N	$N, \%$	$\sum_1^d N, \%$	Nd^3	N	$N, \%$	$\sum_1^d N, \%$	Nd^3
1	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—
3	7	0,31		189	—	—	—	—	—	—	—	—
4	55	8,46	3,17	4160	3	0,31		492	—	—	—	—
5	383	17,12	20,29	45825	123	12,62	12,93	15375	67	8,74		8077
6	591	26,03	46,31	127075	251	25,75	38,68	54216	201	26,21	34,95	43116
7	651	28,63	74,93	220208	286	29,35	68,03	98263	229	29,69	64,64	93021
8	310	14,95	89,91	171090	162	16,67	84,70	82944	159	20,73	85,37	83656
9	143	6,29	96,23	104247	88	9,05	93,75	64152	37	4,83	90,20	26973
10	54	2,37	98,60	54000	25	2,57	96,32	25000	35	4,59	94,79	35000
11	15	0,66	99,26	13915	19	1,95	98,27	23589	12	1,56	96,35	17292
12	13	0,57	99,83	22464	9	0,92	99,19	15552	7	0,91	97,26	13608
13	1	0,04	99,87	2197	4	0,41	99,60	8788	2	0,26	97,52	4394
14	2	0,09	99,96	5488	1	0,10	99,70	2744	2	0,26	97,78	5488
15	1	0,04	100,00	3375	—	—	99,70	—	—	—	97,78	—
16	—	—	—	—	1	0,10	99,80	4096	—	—	97,78	—
17	—	—	—	—	—	—	99,80	—	—	—	97,78	—
18	—	—	—	—	—	—	99,80	—	2	0,26	98,04	11664
19	—	—	—	—	—	—	99,80	—	1	0,13	98,17	6859
20	—	—	—	—	—	—	99,80	—	—	—	98,17	—
21	—	—	—	—	1	0,10	99,90	9261	—	—	98,17	—
22	—	—	—	—	1	0,10	100,00	10648	—	—	98,17	—
23	—	—	—	—	—	—	—	—	1	0,13	98,30	12167
24	—	—	—	—	—	—	—	—	1	0,13	100,00	13824
25	—	—	—	—	—	—	—	—	—	—	—	—
Σ	2272	100,00	—	789739	974	100,00	—	416857	767	100,00	—	367
per 1 mm of glass	978	—	—	340000	466	—	—	185000	445	—	—	1[illegible]

TABLE 3. THE DISTRIBUTION SPECTRA OF DROPLETS OBTAINED WITH TWO COLLECTORS ON THE 3rd OF MARCH 1962

dyu	1st experiment				2nd experiment				3rd experiment				4th experiment			
	narrow		wide		narrow		wide		narrow		wide		narrow		wide	
	N	N, %	N	N, %	N	N, %	N	N, %	N	N, %	N	N, %	N	N, %	N	N, %
2	1	0,15	1		1		1									
3	62	9,31	87	12,03	20	16,53	14	1,90	6	1,49	4	0,52	3	0,70	1	
4	77	11,56	81	11,20	30	24,80	59	8,02	29	7,21	19	2,45	16	2,33	14	
5	83	12,47	78	10,79	16	13,22	153	21,87	52	12,94	60	7,74	25	5,83	24	
6	74	11,11	65	8,99	23	19,01	157	21,33	40	9,95	55	7,09	38	8,86	19	
7	90	13,51	77	10,65	23	19,01	113	15,35	51	12,69	76	9,80	48	11,19	78	
8	99	14,87	112	15,50	7	5,78	90	12,33	74	18,41	117	15,10	80	18,64	111	
9	67	10,06	69	9,54	2	1,65	67	9,10	59	14,68	106	13,67	70	16,31	83	
10	44	6,61	42	5,81			24	3,26	35	8,71	64	8,26	47	10,96	46	
11	25	3,75	41	5,76			17	2,31	24	5,97	100	12,92	36	8,39	78	
12	9	1,35	32	4,43			9	1,22	12	2,98	53	6,84	25	5,83	57	
13	12	1,80	19	2,63			1	0,14	3	0,75	53	6,84	28	6,53	37	
14	11	1,65	12	1,66			2	0,27	10	2,49	35	4,52	16	3,76	43	
15	7	1,05	—	—			—	—	4	1,0	14	1,80	2	0,46	11	
16	2	0,30	3	0,41			—	—	1	0,25	10	1,29	1	0,23	15	
17	1	0,15	3	0,41			—	—	1	0,25	5	0,64	—	—	4	
18	1	0,15	1	0,18			—	—	—	—	3	0,39	1	0,23	1	
19	—	—	—	—			—	—	—	—	—	—	2		2	
20	—	—	—	—			—	—	1	0,25	1	0,13	1	0,23	2	
21	1	0,15	1	0,18			—	—	—	—	—	—	—	—	2	
24	—	—	—	—			—	—	—	—	—	—	—	—	1	
Σ	666	100,00	723	100,00	121	100,00	735	100,00	402	100,00	775	100,00	429	100,00	623	100,00
Σ of glass	293	—	488	—	87	—	595	—	232	—	574	—	206	—	179	—

TABLE 4. THE DISTRIBUTION SPECTRA OF DROPLETS OBTAINED WITH TWO COLLECTORS

d, μ	August 17								August 19							
	1st test				2nd test				1st test				2nd test			
	narrow		wide		narrow		wide		narrow		wide		narrow		wide	
	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %
3	1	0,07	—	—	—	—	—	—	—	—	2	0,27	2	0,14	—	—
4	5	0,37	—	—	—	—	—	—	4	0,34	1	0,13	—	—	—	—
5	11	0,81	5	1,47	—	—	4	1,37	26	2,21	29	3,89	15	1,22	3	0,37
6	31	2,30	24	7,10	21	6,84	23	11,44	91	7,81	74	10,00	111	7,81	45	5,59
7	103	9,60	76	22,48	61	19,87	47	23,15	216	18,62	191	25,00	265	18,65	163	19,92
8	229	17,00	106	31,37	75	24,46	56	27,70	265	22,87	215	28,80	373	26,26	213	26,07
9	196	14,00	65	19,23	49	15,96	36	17,73	123	10,60	119	15,87	214	15,06	153	18,70
10	174	12,90	25	7,25	43	14,01	26	12,81	131	11,55	56	7,52	141	10,13	129	15,77
11	73	5,41	7	2,07	15	4,55	6	2,99	81	6,96	22	2,95	87	6,12	45	5,50
12	118	8,74	12	3,55	30	9,77	3	1,48	80	7,11	19	2,55	92	6,47	48	5,86
13	111	8,22	9	2,66	6	1,95	1	0,49	65	5,60	9	1,21	59	4,15	15	1,83
14	24	1,78	1	0,30	3	0,98	1	0,49	18	1,55	1	0,13	15	1,27	—	—
15	55	4,07	3	0,89	1	0,32	—	—	27	2,33	2	0,27	20	1,41	2	0,24
16	46	3,40	—	—	1	0,32	—	—	12	1,03	1	0,13	5	0,35	1	0,12
17	56	4,15	—	—	1	0,32	—	—	7	0,60	—	—	9	0,63	—	—
18	34	2,52	—	—	—	—	—	—	2	0,17	—	—	1	0,07	1	0,12
19	25	1,85	2	0,60	—	—	—	—	—	—	—	—	1	0,07	—	—
20	11	0,81	—	—	1	0,32	—	—	—	—	—	—	—	—	—	—
21	6	0,44	—	—	—	—	—	—	—	—	—	—	1	0,07	—	—
22	3	0,22	—	—	—	—	—	—	1	0,09	—	—	—	—	—	—
23	3	0,22	—	—	—	—	—	—	1	0,09	—	—	1	0,07	—	—
24	5	0,37	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	2	0,15	—	—	—	—	—	—	—	—	—	—	—	—	—	—
26	4	0,13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	3	0,22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	1	0,09	—	—	—	—	—	—
Σ	1350	100,00	338	100,00	807	100,00	293	100,00	1160	100,00	715	100,00	1421	100,00	818	100,00
per l. mm of glass	560	—	197	—	296	—	148	—	342	—	377	—	517	—	264	—

TABLE 4. (CONTINUED)

d, μ	August 20								August 21							
	1st test				2nd test				1st test				2nd test			
	narrow		wide		narrow		wide		narrow		wide		narrow		wide	
	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %	N	N. %
3	—	—	—	—	—	—	6	2,56	—	—	—	—	—	—	—	—
4	17	1,73	8	5,44	61	8,02	30	12,83	9	0,96	5	0,70	8	0,71	19	1,94
5	131	12,76	33	22,45	155	20,37	63	27,02	83	8,87	63	8,80	83	7,38	149	15,22
6	289	27,74	35	23,82	185	24,37	75	32,06	172	18,48	116	16,47	218	19,39	252	27,74
7	313	31,96	15	10,61	161	21,42	39	16,67	213	22,77	197	27,26	298	26,51	256	26,15
8	189	17,46	22	14,96	90	11,23	8	3,42	136	14,53	168	23,91	295	26,92	161	16,75
9	21	1,99	3	2,04	22	2,89	6	2,56	100	10,68	115	12,91	102	9,05	72	7,35
10	20	1,92	1	0,68	28	3,68	5	2,14	63	6,73	73	7,41	53	1,72	24	2,45
11	1	0,10	—	—	11	1,84	—	—	37	3,95	32	4,15	60	5,11	16	1,03
12	3	0,29	—	—	11	1,44	2	0,85	41	4,38	15	2,13	25	2,19	14	1,43
13	4	0,38	—	—	12	1,58	—	—	35	3,74	12	1,54	19	1,61	8	0,82
14	3	0,29	—	—	3	0,39	—	—	28	2,99	5	0,70	8	0,71	—	—
15	—	—	—	—	3	0,39	—	—	11	1,18	—	—	6	0,53	3	0,31
16	2	0,19	—	—	2	0,26	—	—	2	0,21	—	—	3	0,27	1	0,10
17	2	0,19	—	—	2	0,26	—	—	3	0,32	—	—	3	0,27	1	0,10
18	—	—	—	—	—	—	—	—	2	0,21	—	—	—	—	—	—
19	—	—	—	—	2	0,26	—	—	1	0,10	—	—	—	—	—	—
20	—	—	—	—	1	0,13	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	1	0,13	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	3	0,39	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	1	0,13	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	2	0,26	—	—	—	—	—	—	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Σ	1042	100,00	147	100,00	761	100,00	231	100,00	995	100,00	1008	100,00	1121	100,00	979	100,00
per l. mm of glass	755	—	107	—	490	—	310	—	541	—	556	—	591	—	814	—

TABLE 5. THE DISTRIBUTION SPECTRA OF DROPLETS OBTAINED WITH TWO COLLECTORS ON THE 19th OF AUGUST 1962

	narrow										wide				
d, μ	N	N, %	$\sum_1^d$ N, %	Nd³	d	N	N, %	$\sum_1^d$ N, %	Nd³		d	N	N, %	$\sum_1^d$ N, %	Nd³
4	1	0,15	0,15	64	33	5	0,75	86,95	170000		4	11	0,42	0,42	704
5	6	0,89	1,04	750	34	1	0,15	87,10	21400		5	78	3,00	3,42	9750
6	21	3,13	4,17	4536	35	5	0,74	87,87	259200		6	351	13,51	16,93	58104
7	68	10,12	15,29	23324	36	1	0,00	87,47	15680		7	614	23,64	40,57	212387
8	90	13,40	27,69	46080	37	11	1,64	90,11	506240		8	704	27,11	67,68	363008
9	61	9,08	36,77	44469	38	4	0,60	90,71	219488		9	470	18,09	85,77	269730
10	49	7,30	44,07	43960	39	7	1,04	91,75	438900		10	256	9,86	95,63	256000
11	24	3,58	47,65	31944	40	4	0,60	92,35	256000		11	73	2,81	98,44	97163
12	36	5,36	53,01	62208	41	2	0,30	92,65	137842		12	141	5,43	103,87	177984
13	34	5,07	58,08	76908	42	3	0,45	93,10	254520		13	18	1,69	105,56	96658
14	14	2,09	60,17	38416	43	3	0,45	93,55	296283		14	12	0,46	106,02	33928
15	21	3,13	63,30	70875	44	2	0,30	93,85	171776		15	11	0,42	106,44	37125
16	17	2,53	65,83	69632	45	3	0,45	94,30	276480		16	5	0,19	106,64	20480
17	14	2,09	67,92	68782	46	3	0,45	94,75	299268		17	2	0,08	106,72	9826
18	26	3,87	72,09	151632	47	4	0,60	95,35	417840		18	—	—	—	—
19	11	1,64	73,73	79439	48	5	0,75	96,10	553920		19	3	0,12	106,81	20677
20	4	0,60	74,33	32000	49	4	0,60	96,70	384160		20	1	0,04	106,88	8000
21	7	1,04	75,37	64827	50	1	0,15	96,10	111500		21	1	0,04	106,92	9261
22	7	1,04	76,41	74536	51	2	0,30	96,70	234256		22	—	—	—	—
23	9	1,34	77,75	109503	52	4	0,60	97,30	499392		23	—	—	—	—
24	10	1,49	79,24	138240	53	1	0,15	97,50	143370		24	—	—	—	—
25	1	0,15	79,39	15625	54	1	0,15	98,05	170640		25	—	—	—	—
26	11	1,64	81,03	193804	55	3	0,45	98,50	526500		26	1	0,04	106,96	17576
27	10	1,49	82,52	196830	57	3	0,45	98,95	592707		—	—	—	—	—
28	6	0,89	83,41	131712	59	1	0,15	99,10	205379		—	—	—	—	—
29	7	1,04	84,45	170730	61	1	0,15	99,25	226981		—	—	—	—	—
30	4	0,60	85,05	108000	63	1	0,15	99,40	250047		—	—	—	—	—
31	3	0,45	85,50	89373	66	1	0,15	99,55	287496		—	—	—	—	—
32	5	0,74	86,24	163850	68	1	0,15	99,70	314432		—	—	—	—	—
					74	1	0,15	99,85	405224		—	—	—	—	—
					75	1	0,15	100,00	421875		—	—	—	—	—
Σ						671	100,00	—	11[illegible]288		—	2596	100,00	—	1697206
per 1 mm³ of glass						224	—	—	[illegible]		—	418		—	273000

TABLE 6. THE DISTRIBUTION SPECTRA OF DROPLETS IN NATURAL CLOUDS OBTAINED ON THE 30th OF NOVEMBER 1962

	1st test			2nd test			3rd test			4th test			Total		
d, μ	N	N, %	$\sum_1^d$ N, %	N	N, %	$\sum_1^d$ N, %	N	N, %	$\sum_1^d$ N, %	N	N, %	$\sum_1^d$ N, %	N	N, %	$\sum_1^d$ N, %
4	22	18,64	—	1	1,18	—	4	0,84	—	10	11,11	—	37	4,80	—
5	27	22,88	41,53	15	17,65	18,83	71	14,88	15,72	18	20,00	31,11	131	17,01	21,81
6	31	26,27	67,80	31	36,46	55,29	130	27,25	42,97	22	24,41	55,55	214	27,79	49 60
7	22	18,64	86,44	24	28,24	83,53	178	37,32	80,29	10	11,11	66,66	234	30,39	79,99
8	9	7,63	94,07	11	12,94	96,47	60	12,58	92,87	10	17,78	84,44	90	12,47	92,46
9	4	3,39	97,46	2	2,35	98,82	25	5,24	98,11	5	5,56	90,00	36	4,68	97,14
10	3	2,55	100,00	1	1,18	100,00	8	1,68	99,79	6	6,67	96,67	18	2,34	99,48
11	—	—	—	—	—	—	1	0,21	100,00	—	—	96,67	1	0,13	99,61
12	—	—	—	—	—	—	—	—	—	—	—	96,67	—	—	99,61
13	—	—	—	—	—	—	—	—	—	2	2,22	98,89	2	0,26	99,87
14	—	—	—	—	—	—	—	—	—	—	—	98,89	—	—	99,87
15	—	—	—	—	—	—	—	—	—	1	1,11	100,00	1	0,13	100,00
Σ	118	100,00	—	85	100,00	—	477	100,00	—	90	100,00	—	770	100,00	—
per 1 mm³ of glass	265	—	—	382	—	—	567	—	—	203	—	—	433	—	—

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REFERENCES

1. Basevich, V. Ya. Photometric Method of Determining the Number and Dimensions of Atomized Fuel Droplets in a Stream (Fotometricheskaya metodika opredeleniya chisla i razmerov kapel' raspylennogo topliva v potoke) Pribory i Tekhnika Eksperimenta, No. 6, 1957.

2. Borovikov, A. M. Some Results Obtained from the Study of Cloud Elements (Nekotoryye resultaty izucheniya oblachnykh elementov) Trudy TsAO, No. 3, 1948.

3. Zaytsev, V. A. The Microphotography of cloud and fog droplets (Metodika mikrofotografirovaniya kapel'tumana i oblakov) Trudy GGO. No. 9 (71), 1948.

4. Levin, L.M. Investigations on the physics of roughly dispersed aerosols (Issledovaniye po fiziki grubodispersnykh aerozoley) AN SSSR Moscow, 1961.

5. Laktionov, A. G. An automatic continous flow device for investigating natural aerosols (Avtomaticheskiy potochnyy pribor dlya issledovaniya estestvennykh aerozoley) Izvestiya AN SSSR, Seriya Geofiz. No. 5, 1959.

6. Petrov, G. D. Optical Method of determining the spectrum of water aerosol particles (Opticheskiy method opredeleniya spektra chastits vodnogo aerozolya) Izvestiya AN SSSR, seriya geofiz, NO. 5, 1959.

7. Ravinskiy, F. Ya. New methods of recording water droplets (Novyye metody registratsii vodyanykh kapel') Izvestiya AN SSSR, seriya geofiz., No. 7, 1959.

8. Salamandra, G. D., Naboko, I. M. Capture on a plate covered with soot as a method of determining the size of atomized fuel particles (Ulavlivaniye na plastinku, pokrytuyu sloyem sazhi kak metod opredeleniya krupnosti raspylivaniya topliva) Zhurnal Tekhnichenskoy Fiziki, Vol. 27, No. 3, 1957.

The high-speed microphotography of atomized fluid particles in flight (Skorostnoye mikrofotografirovaniye kapel' raspylennoy zhidkosti v polete) (In the same volume).

9. Fuks, N. A. Determining droplet dimensions in water fogs (Opredeleniye razmera kapelek v vodnykh tumanakh) Zhurnal Eksper. i Teoretich. Fiziki, Vol 7, No. 4, 1937.

10. Khmelevtsov, S. S. Errors in the microphotographic method when determining the microstructure of aersols (Pogreshnosti metoda mikrofotografirovaniya pri opredeleniyi mikrostruktury aerozoley) Izvestiya Vysshikh Uchebnykh Zavedeniy, Fizika, No. 3, 1962.

11. Khrgian, A. Kh., Mazin, I. P. Computation of the error in an aircraft droplet collector (Raschet oshibok samoletnogo zabornika kapel', Trudy TsAO, No. 12, 1953.

12. Shifrin, K. S., Golikov, V. I. Determining droplet spectra by the method of small angles (Opredeleniye cpektra kapel' metodom malykh uglov) Collected works "Investigation of clouds, precipitations and static electricity" (Sb. Issledovaniye oblakov, osadkov i groznogo elektrichestva, 1961).

13. Eldridge R. Measurements of cloud drop size distributions. Journal of Meteorology, Vol. 14, N 1, 1957.

14. Farlow, N. H. A physicochemical system for water aerosol measurement. Journal of Colloid Science, N 11, 1956.

15. Frith, R. The size of cloud particles in stratocumulus clouds. Quart. Journ. of the Royal Meterological society, vol. 77, N 333, 1951.

16. Godard, L. Procédé pour déterminer les dimensions des gouttelettes de brouillard ou de nuages Bulletin de l'observatoire du Puy de Dôme, N 1, 1959.

17, Liddele, H. F., Wootten, N. W. The detection and measurement of water droplets. Quart journ. of the Royal Meteorological Society, vol. 83, N 365, 1957.

18. May, K. R. The measurement of airborne droplets by the magnesium oxyde method. Journal Scientific Instrument, N 27, 1950.

19. May, K. R. Detecting Volatile Airborne droplets, Nature, vol. 183, N. 4663, 1959.

20. Mac Cready, P. B., Deloncle M., Picca, R., Admiral, P., Dessens, J., Serpolny, R., Saulage, G., Toye, M. S., Dessens, H., Godard, S. Compte rendu du meeting de comparison des capteurs de gouttelettes. Bulletin de l'observatoire du Puy de Dôme, N 1, 1962.

21. Okita, Water-Blue Film Method for Measurement of Cloud and Fog Droplets. Journal Meteorol. Soc. Japan 36(4), 1958.

22. Sivadjian, J., Analyse hydrophotographique des gouttelettes de pluie et de brouillard. Comp. Rend. 236 (1), 1953.

23. Straznevskiy, L. Investigation of atomization of liquid fuel. Technical Physics of the USSR., vol. IV, N 11-12, 1937.

24. Vonnegut, B., Neubauer, R. Detection and Measurement of aerosol Particles By the use of an Electrically Heated Filament, Analytical chemistry, vol. 24, N 6, 1952.